# Overview of the Performance of PIT-tag Interrogation Systems for AdultSalmonids at Bonneville and McNary Dams

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**Overview of the Performance of PIT-Tag Interrogation Systems for Adult Salmonids at Bonneville and McNary Dams, 2002**

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Report of research by

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## EXECUTIVE SUMMARY


During the winter of 2001, the U.S. Army Corps of Engineers and Bonneville Power Administration installed a prototype orifice-based PIT-tag interrogation system into the Washington Shore Ladder at Bonneville Dam (BWSL). NOAA Fisheries (NMFS) tagged and released salmonids during 2001 to determine tag-reading efficiencies for different salmonid populations. The BWSL system detected 97% of the spring chinook salmon, but in the fall it was discovered that coho and fall chinook salmon used the weir overflows at a much higher rate and thus avoided detection. During 2001, technology advances led to the development of significantly larger antennas (2 × 6 ft). Thus, it became feasible to design interrogation systems for ladder locations where all fish would have to go through the antennas.

Although the orifice-based systems appeared less effective for some salmonid populations, the decision was made to proceed with installations planned for Bonneville and McNary Dams because valuable data would still be collected. In addition, a prototype system was installed into the counting-window area in the McNary Oregon Ladder (MOL) where its performance could be directly compared to the orifice-based system in the same ladder. This overview provides information on how PIT-tag interrogation systems at Bonneville and McNary Dams performed during 2002.

### Tag-Reading Performances of Counting-Window and Orifice-Based Interrogation Systems in the McNary Oregon Ladder

The orifice-based and counting-window interrogation systems in the MOL became operational on 9 April 2002. The prototype counting-window system underwent several developmental improvements over the season and was finalized on 14 August. From 15 August through 31 October, preliminary radiotelemetry data yielded 728 radio-and PIT-tagged salmonids that were ***last*** detected at the top of the MOL and had not ascended the Washington Ladder.

The two PIT-tag systems together detected 726 fish or 99.7% of the double-tagged fish detected by radiotelemetry receivers. The counting-window system detected 98.2% and the orifice-based system detected 99.2% of the double-tagged fish. The orifice-based system probably detected more fish because it had 16 antennas compared to 2 for the prototype counting-window system.

From 15 August through 31 October, 2,295 river-run migrating adult salmonids were detected by one or both PIT systems. Each system independently detected around 98.5%.

Of the spring/summer chinook salmon that were later detected at Lower Granite Dam, the orifice-based system detected 83% of the 2-year-old jacks while the counting-window system detected 94%. For adult chinook, the orifice-based system detected 99.9% and the counting-window system detected 96%. A similar trend was seen for fall chinook jacks and adults. Therefore, it appeared that both interrogation systems detected adult chinook salmon better than jacks.

During July, transceivers in the orifice-based system experienced temperatures above their optimum operating maximums, which caused them to miss reading a number of double-tagged fish (reading efficiency decreased to 90%). Pacific States Marine Fisheries Commission (PSMFC) is considering installing air-conditioned outbuildings to house the transceivers at MOL for 2003.

## Reading Efficiencies of the Orifice-Based System in the Bonneville Washington Shore Ladder

In 2002, NMFS tagged 216 fall chinook salmon, 157 coho salmon, and 250 steelhead at Bonneville Dam. Reading efficiencies for BWSL were 72.7, 79.0, and 90.4% for fall chinook, coho, and steelhead, respectively. Of the fish not detected at Bonneville Dam, a significant number of fall chinook salmon and steelhead were detected at McNary Dam. Overall detection rates were 88.0, 79.6, and 96.0% for fall chinook, coho, and steelhead, respectively.

The BWSL-only reading efficiency results in 2002 compared to 2001 were much lower for fall chinook (2001-90.3%), slightly lower for steelhead (2001-94.8%), and about the same for coho salmon (2001-75.9%). Based on the results for 2001 and 2002, the proportions of test fish that primarily used the orifices (those fish detected in at least seven of the eight weirs) appeared to directly correlate to the reading efficiencies for the different salmonid populations.

As with the results in 2001, it must be emphasized that the primary cause for the lower reading efficiencies for fall chinook and coho was fish behavior (i.e., weir overflow use) and not the failure of orifice-based antennas to detect fish transiting them.

## Orifice Passage Behavior in Fish Ladders at Bonneville and McNary Dam

A 25% difference in detection rates of fall chinook salmon between BWSL and MOL in 2002 (72.7 and 99.6% respectively) made us question whether fish behavior was significantly different between ladders. Each of the fish ladders at Bonneville and McNary Dams is designed differently. To look at the impact of ladder design on the level of orifice use by fish, we analyzed the proportions of river-run migrating adult salmonids that primarily used the orifices (those fish detected in at least seven of the eight weirs) as they ascended each ladder.

Results for ladders at both dams strongly suggested that fall chinook salmon might use the weir overflows more in ladders that have partial overflows than ladders with full overflows.

The orifice-based system in MOL detected all salmonid populations at higher rates than the system in BWSL because a higher proportion of each salmonid population primarily used the orifices in that ladder. At least 90% of each salmonid population primarily used the orifices in the MOL, while the proportion of primary use in the BWSL ranged from 40 to 80%.

As was observed at McNary Dam, the orifice-based systems at Bonneville Dam missed more jacks than adults. Despite being active only about half of the day, the flume-based system in the Adult Fish Facility at Bonneville Dam detected 7% more jacks than were detected by the orifice-based system, while all adults detected by the flume-based system were also detected by the orifice-based system.

### Reading Efficiencies based on Radio-Tagged and PIT-Tagged Salmonids

Radiotelemetry data for spring/summer and fall chinook salmon that were radio and PIT tagged in 2002 have been processed by the University of Idaho to determine migration routes through Bonneville and McNary Dams. We analyzed how many double-tagged chinook salmon that had been documented as having passed a dam based on radiotelemetry data were also detected by the PIT-tag systems. The PIT-tag interrogation systems in the different fish ladders at Bonneville and McNary Dam missed 3 to 7% of the double-tagged spring/summer chinook salmon.

The 12-weir orifice-based PIT-tag interrogation system in the BWSL missed around 20% of fall chinook salmon, and the antennas in the upper eight weirs missed almost 40%. In contrast, most of the other interrogation systems at Bonneville and McNary Dam detected more than 95% of the double-tagged fall chinook salmon. These results support conclusions from concomitant analyses reported here, which demonstrated that fall chinook salmon used weir overflows in BWSL more than they did in other fish ladders.

### Visual Fish Counts vs. PIT-Tag Detections

Over the years, people have questioned the accuracy of fish counts at counting windows. With PIT-tag systems at both Bonneville and McNary Dams, we compared how well PIT-tag detections and fish counts matched. The 2002 fish count for adult spring chinook salmon at McNary Dam was 48.1% of the total detected at Bonneville Dam. The PIT-tag systems at McNary Dam detected 52.5% of Snake River spring chinook adults detected at Bonneville Dam. Thus, for spring chinook adults, the two approaches yielded similar proportions.

### Performance of Orifice Antennas Containing Moisture

In April 2002, around 25% of the fiberglass orifice antenna housings that were installed in 2002 were identified as probably containing moisture. Three times during the season, PSMFC tested all of the antennas with a megohmmeter. These tests showed that most antennas remained consistent over all sets of measurements, but others did change their moisture status. Over the entire 2002 season, around 20% of antennas installed into fish ladders consistently measured as containing moisture.

We compared the average number of reads/fish at BWSL for April 2001 and 2002. The comparison showed that the performance of the antennas containing moisture in April 2002 was equal to or better than it was in April 2001. Therefore, it appeared that the antennas containing moisture had not degraded over time. Furthermore, a *t*-test comparing the number of reads/fish for the leaking and non-leaking antennas in 2002 was insignificant, with means of 19.1 and 18.8 reads/fish, respectively. Thus, there did not appear to be any difference in the ability of antennas to read tags based on moisture content.

Analyses conducted during the rest of the year (May-September) on all of the ladders demonstrated that antennas with an average number of reads/fish less than five were missing tagged fish occasionally. Of the nine orifice antennas that averaged less than five reads/fish, only two were from the list of antennas mostly containing moisture; none was from the definite group of antennas containing moisture. Therefore, there are other reasons besides having some moisture in the antennas for these systems to miss detecting fish. It needs to be emphasized that these are new systems and we are still learning how to improve their performances.

No antennas failed during 2002. Analyses of all of the antennas using number of reads/fish, weir counts, and transceiver current and voltages did not consistently identify any single antenna that was weak. Thus, the decision was made in mid September not to replace any of the antennas during the 2002-2003 dewatering period.

## CONTENTS

# INTRODUCTION

During winter 2001, the U.S. Army Corps of Engineers (Corps) and Bonneville Power Administration (BPA) installed a prototype orifice-based PIT-tag interrogation system into the Washington Shore Ladder at Bonneville Dam (BWSL). Detectors were installed into 12 weirs: 4 downstream (Weirs 334-337) and 8 upstream (Weirs 352-359) from the fish release point (i.e., the exit ladder for the Adult Fish Facility).

NOAA Fisheries (National Marine Fisheries Service – NMFS) tagged and released salmonids during 2001 to determine tag-reading efficiencies for different salmonid populations. Data analyses focused on the upper eight weirs. The 2001 tagging results for spring chinook salmon indicated that having detectors in four consecutive weirs would have been sufficient to yield a reading efficiency of 95%. The BWSL orifice-based system performed well until the coho and fall chinook salmon migrations began. Coho and fall chinook salmon appeared to use the weir overflows, and thus avoid detection, at much higher rates than biologists expected.

During 2001, technology advances led to the development of significantly larger antennas than had been available earlier, and thus it was possible to build antennas of approximately 2 × 6 ft. Consequently, it became feasible to design interrogation systems for ladder locations where <u>all</u> fish would have to go through the antennas and thus could not avoid detection by using the weir overflows (Fig. 1). Destron Technologies by Digital Angel[†] designed a prototype interrogation system with two antennas that was installed into the counting-window area in the Oregon Ladder at McNary Dam, where its performance could then be directly compared to that of the orifice-based system in the same ladder.

Although the orifice-based systems appeared less effective than the fisheries community wanted for fall chinook and coho salmon, the decision was made to proceed with installations planned for Bonneville and McNary Dams because valuable data would still be collected. During the winter of 2002, the Corps and BPA installed PIT-tag interrogation systems into the Bradford Island and Cascades Island Fish Ladders at Bonneville Dam and into the Washington and Oregon Ladders at McNary Dam. Like BWSL in 2001, these ladders had eight weirs (16 orifices) outfitted with fiberglass antennas. Douglas County Public Utility District also installed an orifice-based system into its ladders at Wells Dam, but they were able to use weirs with no overflow sections wherein all fish had to swim through the orifice antennas. Thus, 2002 was the first year that the fisheries community had PIT-tag detection of adult salmonids at Bonneville, McNary, Wells, and Lower Granite Dams (Fig. 2). This overview will provide information on how well the systems at Bonneville and McNary Dams performed.

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[†] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

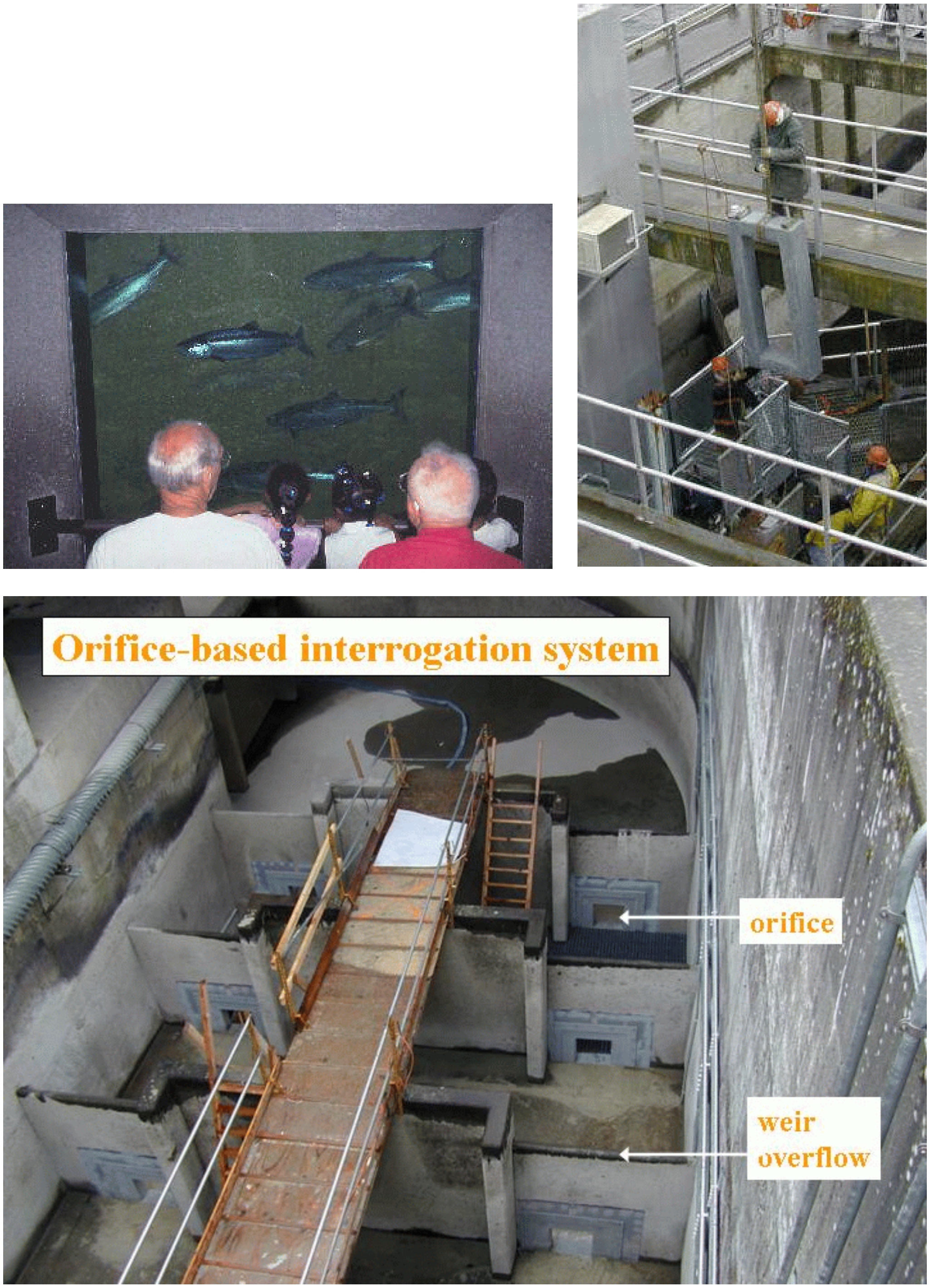


Figure 1. A fish viewing window similar to the counting windows in ladders at Bonneville and McNary Dam (top left), antenna installation at the McNary Dam counting window (top right), and the orifice-based interrogation system at Bonneville Dam (below).

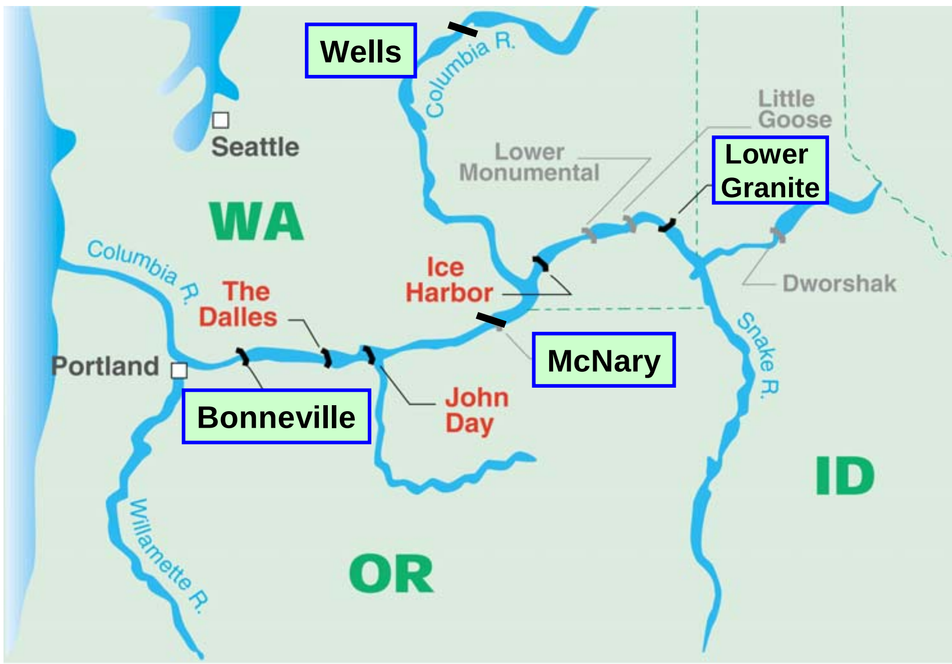


Figure 2. The four dams that had interrogation systems for PIT-tagged adult salmonids in 2002.

For this overview, we had six objectives:

1) Compare tag-reading performances of the counting-window and orifice-based interrogation systems in the McNary Oregon Ladder using three groups of salmonids.

2) Determine reading efficiencies of the orifice-based system in the Washington Shore Ladder at Bonneville Dam using salmonids tagged in the Adult Fish Facility (direct evaluation).

3) Compare salmonid behavior regarding orifice use in all ladders at Bonneville and McNary Dam.

4) Determine reading efficiencies of the individual ladders at Bonneville and McNary Dams using radio-tagged and PIT-tagged salmonids (direct evaluation).

5) Compare proportions of fish counts for Bonneville and McNary Dams using numbers reported from the counting windows and the PIT-tag data.

6) Determine how the antennas identified as containing moisture read tags and maintained tune relative to the non-leaking antennas.

Although the numbers reported in the following evaluations may change slightly as more data are processed, we do not anticipate significant change in the overall trends described.

## TAG-READING PERFORMANCES OF COUNTING-WINDOW AND ORIFICE-BASED INTERROGATION SYSTEMS IN THE MCNARY OREGON LADDER

### Introduction

The counting-window and orifice-based interrogation systems in the McNary Oregon Ladder (MOL) became operational on 9 April 2002. The prototype interrogation system at the counting window underwent several developmental improvements over the season. Initially, the two large antennas (inside dimensions were 19.5 × 63 in) appeared to detune randomly. An investigation determined that because the Corps periodically adjusted water flow conditions during April; the water level in the ladder varied by a few inches, and these fluctuations affected the tune of the antennas. This was not a concern once the reason for the detuning was identified because the water adjustments stopped soon after.

Other initial changes included Pacific States Marine Fisheries Commission (PSMFC) running a ground strap from the AC duplex outlet ground to the transceiver enclosure back panel to reduce the sensitivity to slight vibrations caused by people walking around the site. The grating and handrails of the outside metal walkway were also secured better to reduce the vibrations. Also, Destron Technologies installed new analog boards in the transceivers. Analysis of the PIT-tag data during May demonstrated that fish were being missed primarily during the afternoon, and it was concluded that the sun was heating the fiberglass antenna housings and the enclosed polypropylene capacitors, which caused the antennas to be detuned (Downing 2002). Destron Technologies covered the antenna housings with Styrofoam[†] on 22 May to reduce the large increases in temperature; this significantly reduced the problem.

On 31 July, Destron Technologies installed copolymer-polypropylene antennas with mica capacitors without dewatering the MOL--a task that would not have been possible for the orifice-based system because it is designed for such maintenance work to be conducted during the winter dewatering period. On 14 August, Destron Technologies then replaced the mica capacitors, which had decayed significantly during the first 2 weeks, with ceramic capacitors, which appeared to handle temperature changes better than all other capacitors tested in the laboratory (Sean P. Casey, Destron Technologies, Personal communication). As the analysis below will show, these modifications definitely improved performance; however, even prior to the modifications in May, performance was very good considering this was a prototype system that consisted of only two antennas.

To compare the tag-reading performances of the counting-window and orifice-based interrogation systems in MOL, three different groups of fish were used: adults double-tagged with radio and PIT tags, adults with PIT-tags recorded in the PIT-Tag Information System (PSMFC 1996), and migrating salmonids that were detected at Lower Granite Dam in 2002 (and thus should have been previously detected at Bonneville and McNary Dams).

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## Radio-Tagged and PIT-Tagged Salmonids

As part of a joint project between University of Idaho and NMFS, adult chinook salmon and steelhead were radio tagged in the Adult Fish Facility that is connected to the BWSL. Radio tags were gastrically implanted and the fish were also scanned for PIT tags. The fish were then PIT tagged only if no existing PIT tag was detected. The double-tagged salmonids were then released at various sites below and above Bonneville Dam and tracked as they migrated up the Columbia River. Radiotelemetry systems use many more antennas than PIT-tag interrogation systems to cover all of the possible migration pathways at a dam (i.e., fish ladders and navigation locks).

We used the radiotelemetry data to confirm that double-tagged fish had indeed ascended MOL when they were undetected by either or both PIT-tag interrogation systems. For this analysis, we could only utilize data from double-tagged fish which were tagged with 134.2-kHz PIT tags because these interrogation systems are 134.2-kHz systems (i.e., they are not designed to and will not read 400-kHz tags).

There are radiotelemetry antennas throughout the MOL so that fish can be tracked entering the ladder, transiting the middle of the ladder (where the orifice antennas are), and leaving the ladder (just above the counting window; Fig. 3). At the top of the ladder, one radiotelemetry antenna is located below the counting window and two are located above it. Radiotelemetry data needs to be hand checked to ensure that the passage route of each fish is correctly categorized because there can be false detections at individual receive antennas. By January, only the spring/summer chinook data had been checked and completely processed. Fall chinook data were processed in April, and steelhead data will not be processed until later in 2003. In order to include steelhead in our analyses, we will utilize some preliminary data, which provides the location of the last antenna where an individual fish was observed.

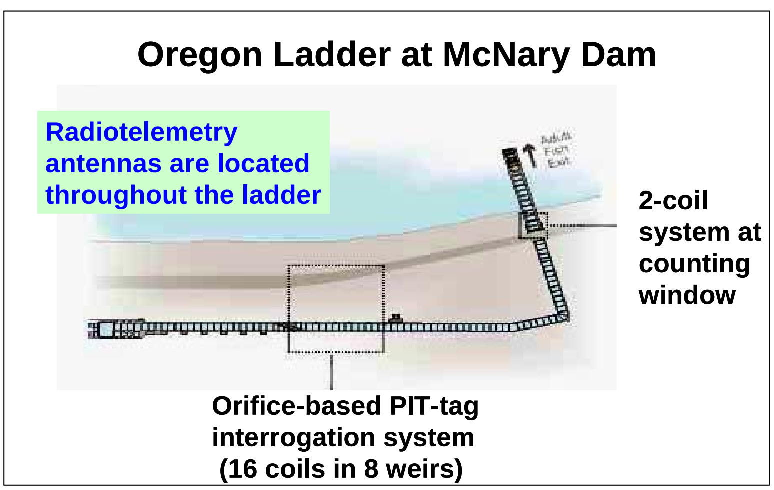


Figure 3. McNary Oregon Ladder showing locations of the two PIT-tag systems.

## Tag-Reading Efficiencies

We know that some PIT-tagged fish were missed by the counting-window system while Destron Technologies was making changes to improve the performance of the prototype. Therefore, the fairest evaluation was to compare tag-reading performances between the two systems after 14 August when the last change was made to the counting-window system (Table 1). From 15 August through the end of October, the preliminary radiotelemetry data contained records of 734 double-tagged salmonids being *last* detected at the top of the MOL. After the end of October, the counting station was closed and the picketed leads were raised; therefore, fish using the ladder would no longer have to pass through the counting-window antennas.

Since all radiotelemetry data have not yet been processed, it may be that some double-tagged fish only passed near the top of the MOL before heading upstream and therefore did not actually ascend MOL. If we omit the six fish that most likely ascended the Washington Ladder, based on the PIT-tag systems in both McNary ladders, then the two PIT-tag systems in the MOL detected 726 out of 728 fish, or 99.7% (Table 1). In April, except for one steelhead out of this group, we were able to use radiotelemetry data to confirm that the other five fish had ascended the Washington Ladder. Furthermore, there was solid radiotelemetry evidence that the two fish not detected by the two PIT-tag systems ascended MOL.

To make it easier to compare the PIT-tagged and radio-tagged fish to other groups of fish that are just PIT tagged, we included a category that employs a more conservative definition for ascension than mere presence in the ladder. To count as definitely ascending the ladder, fish had to be last detected on one of the three uppermost weirs. Results showed that the counting-window system detected 98.2% and the orifice-based system detected 99.2% of all double-tagged fish (seven more fish with the conservative comparison).

Table 1. Numbers and percentages of double-tagged fish that ascended the McNary Oregon Ladder between 15 August and 31 October 2002 based on preliminary radiotelemetry data that indicate fish were last detected at the top of the ladder. Values were adjusted for fish that appeared to have ascended the Washington Ladder based on PIT-tag data.

| PIT-tag system | Detections N | Detections % |
|---|---|---|
| Total fish tagged with PIT-tag and radio-tag | 728 | 100.0 |
| Orifice and counting window | 726 | 99.7 |
| Counting window | 715 | 98.2 |
| Orifice-all detections | 724 | 99.5 |
| Orifice-definitely ascending MOL | 722 | 99.2 |

For other purposes, researchers or managers may only want to know whether a fish was detected at a dam or in a ladder. There were a few cases wherein a double-tagged fish was detected only once in the MOL, but was subsequently detected upstream. If these fish had not been radio-tagged, we would not have definitively known that the fish had continued up the ladder because they could have used the navigation lock to pass the dam.

One reason the orifice-based system probably detected more fish was that it had 16 antennas, while the prototype counting-window system had 2 antennas. The technical group for Adult PIT-Tag Oversight Committee has stressed that future counting-window systems or systems installed into vertical slots need a minimum of three and preferably four antennas to ensure high tag-reading efficiency rates. Additional antennas are also necessary because a PIT-tagged fish that lingers near a single antenna in the counting-window system will prevent the detection of other tagged fish by that antenna (this was observed this year).

**Effect of Summer Heat on Tag-Reading Performance**

Based on preliminary data for the top of the MOL over the whole year, half of the double-tagged salmonids detected by radiotelemetry receivers but undetected by either PIT-tag system were steelhead (24/45). Since the steelhead radiotelemetry data will not be processed by University of Idaho until later in 2003, we used a relative comparison to evaluate the 2002 monthly performance of the two MOL PIT-tag systems rather than omit half of the tagged fish from our analysis. We included fish that were recorded by either PIT system, but removed from analysis any fish that appeared to have ascended the Washington Ladder based on PIT-tag data (typically, these fish were recorded on only the bottom two weirs before leaving MOL). This approach had proven accurate in the analysis of data from 15 August to 31 October, which is described above.

Looking at the month-by-month breakdown, one notes that most double-tagged fish were missed by the orifice-based system in July and by the counting-window system in August (Table 2). During July, the orifice-based system transceivers experienced daytime temperatures that were above their optimum operating maximums. Such high temperatures can cause internal electromagnetic noise levels to rise significantly, which detunes the transceivers and reduces the longevity of the electronic equipment. This detuning caused the orifice-based transceivers to miss a number of double-tagged fish during July (reading efficiency decreased to 90%).

To try to reduce the high air temperatures, PSMFC pumped compressed air into the transceiver enclosures, but this solution was only partially successful. Transceivers for the counting-window system are mounted indoors, where air conditioners help maintain a stable environment, and so they did not experience any heat problems (the antennas and their enclosed capacitors had experienced heat problems in early May, but this was successfully corrected by covering them with Styrofoam).

Partly because measures to reduce the impact of heat on the outdoor transceivers at MOL during summer 2002 were only partially successful, the BPA and its subcontractors requested that temperature-controlled boxes be used for the installations at Ice Harbor and Lower Granite Dams scheduled for early 2003. Furthermore, PSMFC is considering installing air-conditioned outbuildings to house the transceivers at MOL for 2003 (these results certainly support that decision).

Table 2. Numbers and relative percentages (by month) of PIT-tagged and radio-tagged salmonids detected by the counting-window and orifice PIT-tag systems in the McNary Oregon Ladder.

| | April-May | | June | | July | | Aug | | Sept | | Oct | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PIT-tag system | N | % | N | % | N | % | N | % | N | % | N | % |
| Orifice and counting window | 238 | 100.0 | 99 | 100.0 | 78 | 100.0 | 108 | 100.0 | 400 | 100.0 | 247 | 100.0 |
| Counting window | 224 | 94.1 | 94 | 94.9 | 75 | 96.2 | 99 | **91.7** | 396 | 99.0 | 243 | 98.4 |
| Orifice--all detections | 238 | 100.0 | 95 | 96.0 | 71 | 91.0 | 106 | 98.1 | 399 | 99.8 | 247 | 100.0 |
| Orifice--definitely ascending MOL | 236 | 99.2 | 95 | 96.0 | 70 | **89.7** | 106 | 98.1 | 399 | 99.8 | 247 | 100.0 |

Performance of the counting-window system was poorest during August (Table 2). A further breakdown of the data indicated that the counting-window system performed at its worst during the first half of August, when the mica capacitors, which had been temporarily installed into the new antennas, rapidly decayed over the short period before ceramic capacitors could be installed (Table 3). After installation of the new capacitors, the reading efficiency returned to above 95% levels.

The monthly breakdown in Table 2 also provides information for researchers who want to know how the systems were performing when their study fish passed McNary Dam. Overall, the two interrogation systems performed well over the entire year.

Table 3. Numbers and relative percentages of PIT-tagged and radio-tagged salmonids detected by counting-window and orifice-based PIT-tag detection systems in the McNary Oregon Ladder during August 2002.

| | 1-14 August | | 15-30 August | |
|---|---|---|---|---|
| PIT-tag system | N | % | N | % |
| Orifice and counting window | 29 | 100.0 | 79 | 100.0 |
| Counting window | 23 | **79.3** | 76 | 96.2 |
| Orifice-all detections | 29 | 100.0 | 78 | 98.7 |
| Orifice-definitely ascending MOL | 28 | 96.6 | 77 | 97.5 |

## River-run Adult Migrants

The second group of salmonids used to compare reading efficiencies between the orifice-based and counting-window systems in the MOL were river-run migrant adults that ascended between 15 August and 31 October, and that had been detected by one or both PIT-tag systems. In contrast to the evaluation using double-tagged salmonids, this evaluation was indirect: we could not directly account for fish that were missed by both systems. With this indirect method, all jacks were omitted from analysis, and adults were omitted if they were subsequently detected ascending the McNary Washington Ladder or if their detection histories indicated that they were ultimately heading down the MOL.

Of the 2,295 adult salmonids that met the criteria for analysis, both the counting-window system and the orifice-based system detected around 98.5% (Table 4). Seven fish (0.3%) were detected only by the orifice-based system in the lower orifice weirs; these fish had no other records of PIT-tag detection at McNary Dam. Three of these seven were later detected at Lower Granite or Wells Dam. One of the seven had been released as a juvenile directly downstream from McNary Dam, which helps explain why it did not completely ascend the ladder. In fact, PIT-tag data collected over the full year showed a recurring pattern for a small fraction of fish that explored, but did not fully ascend the MOL, and that eventually homed to a hatchery downstream from McNary Dam.

Table 4. Detection numbers and relative percentages for the orifice-based and counting window systems in the MOL between 15 August and 31 October 2002. Detections were of PIT-tagged migrating adult river-run salmonids.

| | 15 August-31 October | |
|---|---|---|
| PIT-tag system | N | % |
| Orifice and counting window | 2,295 | 100.0 |
| Counting window | 2,261 | 98.5 |
| Orifice-all detections | 2,265 | 98.7 |
| Orifice-definitely ascending MOL | 2,258 | 98.4 |

## Fish Detected at Lower Granite Dam

The third group of salmonids used to compare the reading efficiencies of the two PIT-tag systems were PIT-tagged salmonids detected at Lower Granite Dam. We chose this group because having been detected at Lower Granite Dam, they should have passed both Bonneville and McNary Dams during their migration. To ensure that these groups had passed a downstream dam, we used only records that showed evidence of detection or transport below Bonneville or McNary Dam during the juvenile or adult migration. We analyzed spring and fall chinook salmon tagged with 134.2-kHz ISO tags. Although we recognize that the counting-window system was still undergoing changes during this analysis, we believe that the fisheries community should be made aware of the trend we observed in the detection of jacks.

We observed a significant difference in reading efficiencies between 2-year-old jacks and adult spring chinook (Table 5). Of the 134 jacks at McNary Dam, PIT-tag systems in both ladders combined detected 130 or 96.7%. Of the jacks detected by PIT-tag systems, 114 ascended MOL, where the orifice-based system detected 83.3% and the counting-window system detected 93.9%. For a subsample of 922 adult spring chinook, PIT-tag systems in both ladders detected 918 or 99.6% (two of the missed fish were also radio tagged; radiotelemetry data confirmed they ascended the McNary Washington Ladder). Of adults detected by the PIT-tag systems, 724 ascended MOL where the orifice-based system detected 99.9% and the counting-window system detected 96.0% (most were missed in early May when sun heating the antennas was causing transceiver tune problems). Therefore, it appeared that for spring/summer chinook, behavior was different between jacks and adults in terms of the use of orifices and weir overflows. Jacks apparently used the weir overflows more than adults, and consequently the orifice-based system did not detect the jack population as well as the counting-window system.

Table 5. Reading efficiencies (%) at McNary Dam by the counting-window and orifice-based systems in MOL for spring chinook salmon that were later detected at Lower Granite Dam, 2002. Fish were 2-year-old jacks (n = 114) and 3-year-old adults (n = 724).

| PIT-tag system | Jacks | Adults |
|---|---|---|
| Counting window (MOL) | 93.9 | 96.0 |
| Orifice (MOL only; all detections) | **83.3** | 99.9 |

A similar analysis was done with 123 2-year-old jacks and 35 3-year-old fall chinook salmon adults that were detected at Lower Granite Dam. These data were all collected after 1 September or after the counting-window system had been finalized. Of the 109 jacks detected by the MOL PIT-tag systems, the counting-window system detected 97.2% and the orifice-based system detected 95.4% (Table 6). All 25 adults that ascended MOL were detected by both systems. For fall chinook salmon, there did not appear to be a dramatic difference in behavior between jacks and adults, but the younger fish were still detected in slightly lower proportions.

Table 6. Reading efficiencies (%) at McNary Dam by the counting-window and orifice-based systems in MOL for fall chinook salmon that were later detected at Lower Granite Dam, 2002. Fish were 2-year-old jacks (n = 109) and 3-year-old adults (n = 25).

| PIT-tag system | Jacks | Adults |
|---|---|---|
| Counting window (MOL) | 97.2 | 100.0 |
| Orifice (MOL only; all detections) | 95.4 | 100.0 |

## Summary and Conclusions

In summary, both the prototype counting-window and orifice-based interrogation systems performed very well, with 98% reading efficiencies for all groups analyzed after 15 August. Both interrogation systems detected adult chinook salmon at higher efficiencies than jacks. This was true to a greater degree with the orifice-based system, which detected 10% fewer spring chinook jacks than the counting-window system. High ambient temperature negatively impacted the outdoor transceivers in the orifice-based system; however, PSMFC is addressing solutions for this problem. With the improvements already made to the counting-window system, and with plans to house the orifice-based transceivers in air-conditioned buildings, the high performance shown by these two systems in 2002 can be expected to improve even further in 2003.

Although the two systems detected adult salmonids well in this ladder, we recommend using the counting-window system or a vertical-slot based system in future installations. These systems should cost substantially less to install, and they have higher reading efficiencies for jacks and for adults in ladders where fish tend to use the overflows. Picketed leads are usually raised when the counting stations are closed at the end of October; consequently, fish using the ladder after that time would not have to swim through the counting-window antennas. Therefore, we recommend that where possible, antennas be installed permanently into vertical slots. Alternatively, the picketed leads could be left in place for the entire winter at ladders with counting-window interrogation systems.

# READING EFFICIENCIES OF THE ORIFICE-BASED SYSTEM IN THE BONNEVILLE WASHINGTON SHORE LADDER

## Introduction

As in 2001, NMFS tagged and released fish in the Adult Fish Facility (AFF) of the Bonneville Washington Shore Ladder (BWSL), and we report results only from fish detected in the upper eight weirs. We tagged fish in August and September 2002 to determine tag-reading efficiencies with a known number of fish. This permitted a comparison to the results from tagging in 2001 and provided information to help managers evaluate whether it would be necessary to install interrogation systems into the counting-window areas or the vertical slots at Bonneville Dam in order to increase overall tag-reading efficiency for the entire dam.

Unlike in 2001, all ladders at Bonneville had orifice-based systems installed during 2002, as did the two ladders at McNary Dam. Therefore, it became possible to get more definitive information on tagged fish that were not detected in BWSL. With no other detection systems available in 2001, there had been some speculation that undetected fish had died, had gone downstream using the overflows, had been tagged twice, or had been tagged at bad angles. However, in both years, fish were hand scanned before and after tagging to help avoid tagging any test fish twice. We also recorded the rare instance when we thought a fish might have been tagged at a bad angle so we could see if the tag angle impacted the tag-reading results.

## Tag-Reading Efficiencies

In August and September 2002, we tagged 216 fall chinook salmon, 157 coho salmon, and 250 steelhead at the Bonneville AFF. The proportion of fall chinook salmon that primarily used the orifices (fish detected in at least seven of the eight weirs) was 41%, which was essentially the same as the 40% proportion displayed by the river-run population (river-run meaning fish that were PIT-tagged as juveniles and are now returning as adults). Test fish from other salmonid populations displayed a similar degree of orifice use relative to their river-run counterparts. Thus, it appears that the passage behavior of fish we tagged was similar to that of the river-run population. Tag-reading efficiencies in the BWSL were 72.7, 79.0, and 90.4% for fall chinook, coho, and steelhead, respectively (Table 7). Only two fish undetected in the BWSL were detected ascending other Bonneville Dam ladders; we assume these fish descended the BWSL and then ascended these other ladders.

Of the fish not detected at Bonneville Dam, a significant number of fall chinook salmon and steelhead were detected at McNary Dam. It should be pointed out that most coho salmon home to locations downstream from McNary Dam and thus would not be detected in its ladders. At Lower Granite and Wells Dam, there were no detections of fish that had not been previously detected downstream. Thus, the overall detection rates for all Bonneville and McNary ladders combined were 88.0, 79.6, and 96.0% for fall chinook, coho, and steelhead, respectively (Table 7).

Table 7. Reading efficiencies (percent detected) for the direct evaluation of the Bonneville Washington Shore Ladder (BWSL) using salmonids tagged and released in the Adult Fish Facility during the fall of 2002. Reading efficiencies are also given for fish detected in the rest of the ladders at Bonneville and for Bonneville and McNary Dams combined.

| Salmonid population | BWSL only | All Bonn. Ladders | All Bonn. & McNary Ladders* |
|---|---|---|---|
| Fall chinook salmon | **72.7** | 73.1 | **88.0** |
| Coho salmon | **79.0** | 79.0 | 79.6 |
| Steelhead B-run | 90.4 | 90.8 | 96.0 |

* No additional detections at Lower Granite or Wells Dam

Reading-efficiency results for BWSL alone were much lower for fall chinook salmon in 2002 than in 2001, slightly lower for steelhead, and about the same for coho salmon (Table 8). To determine if fish behavior explained some of the similarities and differences between results for the 2 years, we examined the proportions of test fish that primarily used the orifices (fish detected in at least seven of the eight weirs).

Table 8. Reading efficiencies (percent detected) from evaluations of the Bonneville Washington Shore Ladder using salmonids tagged and released in the Adult Fish Facility during 2001 and 2002.

| Salmonid population | 2001 | 2002 |
|---|---|---|
| Spring chinook salmon | 97.2 | NA * |
| Summer chinook salmon | 94.4 | NA |
| Fall chinook salmon | 90.3 | 72.7 |
| Coho salmon | 75.9 | 79.0 |
| Steelhead B-run | 94.8 | 90.4 |

* No spring or summer chinook salmon were tagged in 2002.

For steelhead, the proportion of test fish that primarily used the orifices was a little lower in 2002 than in 2001 (Table 9), as was the reading-efficiency value (Table 8). For coho, the proportions of test fish that primarily used the orifices were basically the same in both years (42% in 2001 and 45% in 2002), as were the reading efficiencies. These similar proportions were observed despite the fact that many more coho salmon migrated in 2001 than in 2002 (Table 10 and Fig. 4). Since coho salmon are surface-oriented, they may have continued to use the overflows at the same rate, regardless of fish density in the ladder. There was a large decrease in the proportion of fall chinook salmon that primarily used the orifices in 2002 (41%) compared to 2001 (57%), which reflected the 17% difference in reading efficiencies for fall chinook between the two years.

Table 9. Proportions of the tagged test fish that primarily used the orifices (i.e., were detected in at least seven of the eight weirs) as they ascended the Washington Shore Ladder (BWSL) at Bonneville Dam in both 2001 and 2002.

| Year | Fall chinook | Coho | Steelhead B-run |
|---|---|---|---|
| 2001 | 57 | 42 | 75 |
| 2002 | 41 | 45 | 70 |

In 2002, we tagged fish on two days when numbers of adult fall chinook salmon passing Bonneville Dam were greater than 10,000, while this number was below 10,000 on all days we tagged in 2001. However, on these days we tagged mostly steelhead at the request of other researchers using the facility (Table 10). In fact, we only tagged 26 fall chinook on those two days, and thus most fall chinook were tagged on days when similar numbers of fall chinook were migrating in both years.

The significantly lower number of adult coho migrating during 2002 may have affected the behavior of fall chinook salmon: with less crowding in the overflows, fall chinook may have opted to use them more frequently (Fig. 4). In 2002, the proportions of fish that primarily used the orifices were similar for fall chinook (41%) and coho salmon (45%), and so were their reading efficiencies (72.7 and 79.0%). It appeared that to attain a minimum reading efficiency of 90% in this ladder, that 60% of a population needed to primarily use the orifices.

Some of the difference in the reading efficiencies for fall chinook salmon between the 2 years might also be normal year-to-year variation; this is something we will be able to distinguish as we tag more fish over the next few years. As with the results in 2001, it must be emphasized that the primary cause for the lower detection rates for fall chinook and coho was fish behavior (i.e., weir overflow use) and not that the orifice-based antennas were failing to read fish transiting them. On average, the number of detections per fish was 10-14 during transits of the orifice-based system in the BWSL; only a single read is required for a fish to be recorded as being present.

Table 10. Numbers of adult fall chinook salmon, coho salmon, and steelhead passing Bonneville Dam on days fish were tagged in 2001 and 2002.

| Calendar day | Date | Fall chinook | Steelhead | Coho |
|---|---|---|---|---|
| | | **2001** | | |
| 261 | 09/18 | 7,299 | 7,688 | 14,815 |
| 262 | 09/19 | 4,700 | 6,334 | 9,589 |
| 268 | 09/25 | 2,586 | 2,841 | 1,289 |
| 269 | 09/26 | 2,452 | 2,756 | 1,128 |
| | | **2002** | | |
| 240 | 08/28 | 10,235 | 4,625 | 447 |
| 241 | 08/29 | 17,621 | 4,895 | 588 |
| 259 | 09/16 | 7,872 | 5,395 | 1,655 |
| 260 | 09/17 | 7,576 | 4,582 | 1,828 |
| 269 | 09/26 | 2,985 | 3,445 | 1,456 |
| 270 | 09/27 | 2,335 | 3,400 | 1,376 |

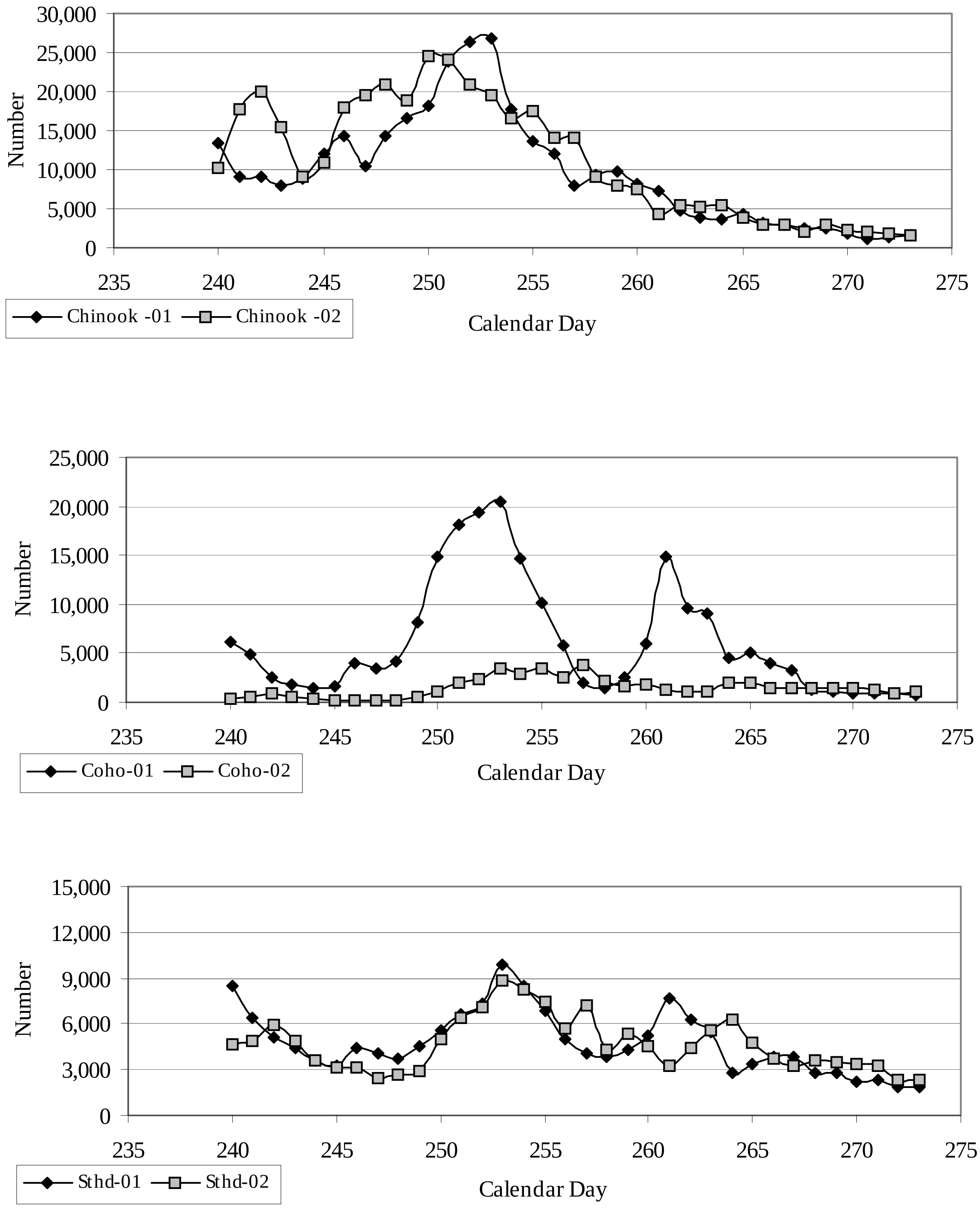


Figure 4. Numbers of adult fall chinook salmon (top), coho salmon (middle), and steelhead (bottom) passing Bonneville Dam each day between 28 August (Day 240) and 30 September (Day 273) of 2001 and 2002.

## Summary and Conclusions

In summary, the proportions of test fish that primarily used the orifices (fish detected in at least seven of the eight weirs) appeared to correlate directly to the reading efficiencies for the different salmonid populations ascending the orifice-based interrogation system in the BWSL. It appeared that to attain a minimum reading efficiency of 90%, that 60% of a population needed to primarily use the orifices. The low reading efficiencies in 2002 for fall chinook and coho salmon support the need to install an interrogation system into the counting-window or vertical-slot areas at Bonneville Dam if the overall PIT-tag reading efficiency is to be raised to meet the requirements of the fisheries community.

However, it should also be pointed out that spring chinook salmon are the primary salmonid populations that are tagged as juveniles and detected as adults (in addition, many of its stocks are ESA listed) and that the orifice-based system detects these populations well because spring chinook tend to use orifices (Tables 8 and 11). Another solution to consider in improving the information on coho salmon and other stocks that home downstream from McNary Dam would be to install adult interrogation systems into The Dalles or John Day Dams.

Table 11. The population distributions (numbers and proportions) for juvenile salmon that were PIT tagged and released in 2002, and for PIT-tagged adult salmon detected at Bonneville Dam for 2002.

| | Juveniles tagged and released, 2002 | | Adults detected, 2002 | |
|---|---|---|---|---|
| Salmonid population | N | % | N | % |
| Spring chinook salmon | 888,277 | 74.2 | 4,298 | 80.0 |
| Fall chinook salmon | 260,438 | 21.8 | 935 | 17.4 |
| Coho salmon | 48,582 | 4.1 | 142 | 2.6 |
| Totals | 1,197,297 | | 5,375 | |

## ORIFICE PASSAGE BEHAVIOR IN FISH LADDERS AT BONNEVILLE AND MCNARY DAM

### Introduction

The radio-tagged and PIT-tagged chinook salmon that were tagged at Bonneville Dam by University of Idaho were divided by run type using the dates defined by the Corps for Bonneville Dam. Therefore, all chinook migrating before 1 June were classified as spring run, those migrating between 1 June and 31 July were summer run, and all migrating after 1 August were fall chinook. Other fish PIT-tagged as juveniles were classified using the run designated by the researchers that had tagged them. We then determined reading efficiencies for the different salmonid populations for MOL (Table 12). Only relative reading efficiencies could be calculated for steelhead because the radiotelemetry data for these fish has not yet been processed by University of Idaho. Coho salmon were excluded from this evaluation because none was radio tagged and because most coho home to locations downstream from McNary Dam and thus would not be detected in its ladders.

There were two notable observations based on the reading efficiencies calculated for MOL (Table12). One was that summer chinook salmon were the only population in which the orifice-based system detected fewer than 95%. As indicated before, we believe the lower reading efficiency rate for summer chinook was mostly due to the transceivers being exposed to high temperatures in the orifice-based system (which detuned the transceivers) rather than fish use of overflows.

Table 12. Numbers and percentages of PIT-tagged and radio-tagged salmonids from four salmonid populations that were detected by the PIT-tag systems in the MOL (McNary Oregon Ladder). Relative values are given for the steelhead because their radiotelemetry data have not been processed yet.

| | Chinook salmon | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Spring | | Summer | | Fall | | Steelhead | |
| PIT tag system | N | % | N | % | N | % | N | % |
| Total number ascending MOL | 296 | -- | 92 | -- | 231 | -- | -- | -- |
| Orifice and counting window | 284 | 95.9 | 92 | 100.0 | 230 | 99.6 | 557 | 100.0 |
| Counting window | 269 | 90.9 | 84 | 91.3 | 228 | 98.7 | 544 | 97.7 |
| Orifice-all detections | 283 | 95.6 | 84 | 91.3 | 230 | 99.6 | 552 | 99.1 |
| Orifice-definitely ascending MOL | 281 | 94.9 | 83 | 90.2 | 230 | 99.6 | 552 | 99.1 |

The second notable observation was the 25% difference in the detection rates of fall chinook salmon between BWSL and MOL in 2002 (72.7 and 99.6% respectively), which made us question whether fish behavior was significantly different between ladders. If fish behavior in terms of orifice and overflow usage were different, this would definitely affect how well the orifice-based interrogation systems performed in different ladders. Therefore, we spent some time examining fish behavior regarding orifice use in the ladders at Bonneville and McNary Dams.

Each of the fish ladders at Bonneville and McNary Dams is designed differently (Table 13). The orifices and pools are different sizes, and some ladders utilize a partial overflow design while others utilize a full overflow design.

Table 13. Dimensions of the fish ladders at Bonneville and McNary Dams.

| | Orifice size (in) | Overflow type | Overflow (ft) | Ladder slope | Ladder width (inches) |
|---|---|---|---|---|---|
| **Bonneville Dam** | | | | | |
| Washington Shore | 18 × 18 | partial | 6 | 1:10 | 24 |
| Bradford A&B Branches | 24 × 24 | partial | 6 | 1:16 | 40 |
| Cascades Island | 24 × 24 | full | 35 | 1:16 | 35 |
| **McNary Dam** | | | | | |
| Washington Ladder | 23 × 21 | full | 30 | 1:20 | 30 |
| Oregon Ladder | 26 × 26 | full | 30 | 1:20 | 30 |

## River-Run Adult Migrants

To evaluate the impact of ladder design on rates of orifice use by fish, we analyzed detections of river-run adult salmonids that had been PIT-tagged previously (mostly as juveniles). For example, we examined the proportions of four salmonid populations that primarily used the orifices (the percentage of fish that were detected in at least seven of the eight weirs) as they ascended (Table 14). Again, there were too few PIT-tagged coho salmon to obtain solid estimates for the different ladders.

Results for the different ladders suggested that fall chinook salmon may use weir overflows more frequently in ladders that have partial overflows than in ladders with full overflows (Table 14). At Bonneville Dam, much lower proportions of fall chinook primarily used the orifices in the three ladders with partial overflows than in the ladder with a full overflow (Cascades Island).

Table 14. Proportions by species of river-run populations that primarily used the orifices while ascending fish ladders at Bonneville and McNary Dams, 2002. Population values are derived from analyzing 75 to 150 river-run adults of each species. Fish were a mixture of wild and hatchery origin; most were PIT-tagged as juveniles. Shading highlights heavy use of overflow weirs by fall chinook salmon in partial vs. full overflow ladders and bold type highlights the consistently lower proportions observed in the BWSL.

| | | Proportion of fish that primarily used the orifices(%) | | | |
|---|---|---|---|---|---|
| Ladder | Overflow type | Spring chinook | Fall chinook | Steelhead (A-run) | Steelhead (B-run) |
| | | **Bonneville Dam** | | | |
| Washington Shore | Partial | **75** | **40** | **80** | **70** |
| Bradford Island (A and B Branch) | Partial | 95 | 65 | 90 | 95 |
| Cascades Island | Full | 90 | 80 | 90 | 90 |
| | | **McNary Dam** | | | |
| Washington Ladder | Full | 97 | 88 | 98 | 90 |
| Oregon Ladder | Full | 95 | 90 | 95 | 90 |

Rates of orifice use were 40% in the Washington Shore Ladder, 65% in both Bradford Island Ladders, and 80% in the Cascades Island Ladder. The two full overflow ladders at McNary Dam also had high proportions of fall chinook primarily using the orifices (~90%). The proportions at McNary Dam might be higher because fewer fish use its ladders; although at the peak of the fall run, approximately the same numbers of fish use both the Bradford Island Ladders and MOL.

For other runs of chinook salmon and steelhead, 90% or more primarily used the orifices in all of the ladders except for BWSL, where proportions of orifice use ranged from 70 to 80% (Table 14). Thus, it appears that the one ladder where we can tag fish for a direct evaluation of the performance of the orifice-based system is the ladder where fish are least likely to use the orifices. However, this mainly impacted fall chinook, as the previous section showed that 60% of a population needs to use primarily the orifices in order to attain a minimum reading efficiency of 90%.

In addition to the partial overflows of the BWSL, this ladder also has the shortest distance between weirs and is the narrowest (Table 13). Since higher proportions of fish from all salmonid populations evaluated used overflow weirs in this ladder, we concluded that there must be something about the BWSL design that encourages this behavior. Another factor that undoubtedly affects fish behavior in the BWSL is that this ladder attracts the highest densities of all fish populations, including shad.

The orifice-based system in MOL detected all salmonid populations at higher rates than the system in BWSL because a higher proportion of each salmonid population primarily used the orifices in that ladder (Tables 12 and 14). At least 90% of each salmonid population primarily used the orifices in MOL while the proportion ranged from 40 to 80% for BWSL.

When such high proportions of salmonids primarily use orifices, then fewer weirs need to be active to achieve high reading efficiencies. During the peak of the spring migration, NMFS found that the orifice-based system in the MOL would have read 98% (1,019) of the 1,038 spring chinook salmon detected by all eight weirs if only the PIT-tag antennas for the bottom two or upper two weirs had been operating (Downing 2002). These results were similar to findings at BWSL in 2001, where the orifice-based interrogation system performed well during the spring migration, and efficiency rates showed that four weirs would have been sufficient to detect 95% of adult spring chinook (Downing and Prentice 2001). Results at MOL during spring 2002 also indirectly supported the conclusion that antennas containing moisture were performing satisfactorily: three of the four antennas in the bottom two weirs in MOL were identified as containing moisture, while no antennas in the upper two weirs were, yet both sets of weirs performed equally well.

## Fish Detected at Lower Granite Dam

To evaluate whether the difference in detection rates between jacks and adult salmon at Bonneville Dam was a result of orifice use vs. weir overflow use in the ladders, we analyzed detections of spring/summer chinook that were later detected at Lower Granite Dam. This was similar to the evaluation mentioned above for McNary Dam.

At Bonneville Dam there is a flume-based interrogation system for adult salmonids in the AFF (this system is designated B2A in PTAGIS) in addition to the orifice-based systems in all of the ladders. The flume-based system is only active when the AFF is used to sample fish; to actively collect fish, a picketed lead is dropped into the BWSL to force fish into the AFF. The fish that go through the B2A antennas should also have passed the four weirs with orifice-based detectors that are located below the entrance into the AFF. Researchers remove some fish, but others (including all jacks since jacks are not radio tagged) continue up the BWSL and thus have another chance to be detected by the orifice-based antennas in the upper section.

For the analysis, we used data from 127 spring/summer chinook jacks and a subsample of 692 adult spring/summer chinook that had been detected at Lower Granite Dam. Despite being active only about half of the day, the flume-based system detected an additional 7% (9 of 127) of jacks that were not detected by the orifice-based system, while all adults detected by the flume-based system (n = 665) were also detected by the orifice-based system (Table 15).

The overall reading efficiencies of both systems for both jacks and adults were below 100% because some fish detected at Lower Granite Dam, which definitely passed Bonneville Dam, went undetected by either system. Similar to the results for McNary Dam, the results for Bonneville Dam showed jacks using the weir overflows more than adult spring/summer chinook salmon.

Table 15. Reading efficiencies by the different PIT-tag systems at Bonneville Dam for spring/summer chinook salmon that were later detected at Lower Granite Dam in 2002. Fish were 2-year-old jacks (n = 127) and 3-year-old adults (n = 692).

| PIT-tag system | Jacks | Adults |
|---|---|---|
| All systems at Bonneville Dam* | 85.8 | 96.1 |
| Orifice-based systems in all ladders | 78.7 | 96.1 |

* This includes all orifice-based systems plus the antennas surrounding the flumes in the Adult Fish Facility (B2A).

## Summary and Conclusions

Ladder design appeared to affect fish behavior in terms of orifice and overflow usage. Results for ladders at both dams strongly suggested that fall chinook salmon might use the weir overflows more in ladders that have partial overflows than ladders with full overflows. At Bonneville Dam, much lower proportions of fall chinook salmon primarily used the orifices in the three ladders with partial overflows (BWSL, 40%; Bradford Island 65% both ladders) than in the Cascade Island Ladder, which has a full overflow (80%). For the other runs of chinook salmon and for steelhead, proportions of fish primarily using the orifices were 90% or higher in all ladders except for BWSL.

The orifice-based interrogation system in the MOL detected salmonid populations at a higher rate than the orifice-based system in the BWSL because a higher proportion of every salmonid population primarily used the orifices in that ladder. At least 90% of each salmonid population primarily used the orifices in the MOL, while this proportion ranged from 40 to 80% in the BWSL. In fact the BWSL had the lowest proportions of fish primarily using the orifices for all salmonid populations.

Thus, it appears that the one ladder where we can tag fish for a direct evaluation of the performance of the orifice-based system is the ladder where the fish use the orifices the least. As was observed at McNary Dam, the PIT-tag systems at Bonneville Dam missed more jacks than adults. This trend is important because jack counts are used to estimate future adult returns.

## READING EFFICIENCIES BASED ON RADIO-TAGGED AND PIT-TAGGED SALMONIDS

### Introduction

Radiotelemetry data from spring/summer (the radiotelemetry researchers do not separate these two populations) and fall chinook salmon that were tagged with both radio and PIT tags in 2002 have been processed by the University of Idaho. They completed the data processing to determine migration routes through Bonneville and McNary Dams during 2002 in April 2003. Normally, these data show whether a fish passed on the Washington or Oregon side of Bonneville Dam but do not distinguish which of the four ladders was used for final passage. For these analyses, NMFS radiotelemetry database manager developed a computer script to provide individual ladder migration information.

Since salmonids often swim up and down multiple ladders at dams (especially Bonneville Dam), we limited our comparison between PIT- and radio-tag detections to the data from ladders that were used during the final ascent at each dam. Furthermore, we analyzed data only from double-tagged fish with 134.2-kHz PIT-tags because interrogation systems in the fish ladders are 134.2-kHz systems (they are not designed to and will not read 400-kHz tags). We also excluded from analysis any double-tagged fish that migrated up Bradford Island and Cascades Island Ladders at Bonneville Dam before noon on 26 April because these PIT-tag interrogation systems were not connected to the data-collection computers before that time.

This analysis determined which double-tagged fish detected by radiotelemetry antennas in the uppermost section of a fish ladder were also detected by PIT-tag systems installed in that ladder. Consequently, we do not report PIT-tag detections of double-tagged fish that were missed by radiotelemetry antennas.

### Tag-Reading Efficiencies

Based on radiotelemetry data, 426 PIT-tagged and radio-tagged spring/summer chinook salmon were categorized as having passed via the Washington side at Bonneville Dam. Of these fish, 131 ascended the Cascades Island Ladder and 295 ascended the BWSL (Table 16). The PIT-tag system in Cascades Island Ladder detected 128 of the 131 fish (97.7%), and the entire 12-weir PIT-tag system in BWSL detected 278 of 295 (94.2%) with 258 (87.5%) detected in the upper eight weirs.

The PIT-tag system in the Bradford Island A Branch detected 133 of the 142 (93.7%) double-tagged salmon that ascended this ladder based on radiotelemetry data., while the system in the B Branch detected 147 of the 151 (97.4%) double-tagged salmon that ascended this ladder. At McNary Dam, the PIT-tag systems in the Oregon and Washington Ladders detected 97.2% (280/288) and 92.6% (226/240) of the double-tagged spring/summer chinook categorized as having passed, respectively.

Table 16. Numbers and percentages of double-tagged (PIT-tagged and radio-tagged) spring/summer chinook salmon that the University of Idaho and NMFS categorized using radiotelemetry data as having passed the different ladders at Bonneville and McNary Dams that were also detected by the PIT-tag systems in 2002.

| Fish ladder | Radio-tag (RT) detections | PIT-tag detections of RT detections | Percentage PIT/RT |
|---|---|---|---|
| **Bonneville Dam** | | | |
| Washington side | 426 | 406 | 95.3 |
| Washington Shore Ladder (all 12 weirs) | 295 | 278 | 94.2 |
| Washington Shore Ladder (upper 8 weirs) | 295 | 258 | 87.5 |
| Cascades Island Ladder | 131 | 128 | 97.7 |
| Oregon side | 293 | 280 | 95.6 |
| Bradford A branch | 142 | 133 | 93.7 |
| Bradford B branch | 151 | 147 | 97.4 |
| **McNary Dam** | | | |
| Washington side | 244 | 226 | 92.6 |
| Oregon side | 288 | 280 | 97.2 |

The detection of double-tagged fall chinook salmon by the BWSL PIT-tag system was relatively poor. Of the 297 fall chinook salmon that ascended BWSL based on radiotelemetry data, the entire 12-weir system detected 80.5% while the upper section of eight weirs detected only 60.9% (Table 17). The PIT-tag system in the Cascades Island Ladder detected 38 of the 42 double-tagged fish that ascended this ladder. The PIT-tag system in the Bradford Island A Branch detected 98.1% of the 161 double-tagged salmon that ascended this ladder based on radiotelemetry data. The PIT-tag system in the Bradford Island B Branch detected 95.5% of the 110 double-tagged salmon that ascended this ladder. At McNary Dam, the PIT-tag systems in the Oregon and Washington Ladders detected 98.2% (228/229) and 99.6%(222/226), respectively.

Based on testing done in Minnesota by Destron Technologies, PSMFC retuned the transceivers in the McNary Washington Ladder differently in early August, and it certainly appeared to improve detection (detection increased from 92.6 to 98.0%).

Table 17. Numbers and percentages of double-tagged (PIT-tagged and radio-tagged) fall chinook salmon that the University of Idaho categorized using radiotelemetry data as having passed the different ladders at Bonneville and McNary Dams that were also detected by the PIT-tag systems in 2002.

| Fish ladder | Radio-tag (RT) detections | PIT-tag detections of RT detections | Percentage PIT/RT |
|---|---|---|---|
| **Bonneville Dam** | | | |
| Washington side | 339 | 277 | 81.7 |
| Washington Shore Ladder (all 12 weirs) | 297 | 239 | 80.5 |
| Washington Shore Ladder (upper 8 weirs) | 297 | 181 | **60.9** |
| Cascades Island Ladder | 42 | 38 | 90.5 |
| Oregon side | 271 | 263 | 97.0 |
| Bradford A branch | 161 | 158 | 98.1 |
| Bradford B branch | 110 | 105 | 95.5 |
| **McNary Dam** | | | |
| Washington Ladder | 229 | 228 | 99.6 |
| Oregon Ladder | 226 | 222 | 98.2 |

## Summary and Conclusions

Radiotelemetry data for spring/summer and fall chinook salmon that were tagged with both radio and PIT tags in 2002 have been processed by the University of Idaho and NMFS to determine migration routes through Bonneville and McNary Dams. We analyzed how many double-tagged chinook salmon that had passed a dam based on radiotelemetry data had also been detected by the PIT-tag systems. The PIT-tag interrogation systems in the different fish ladders at Bonneville and McNary Dam missed 3 to 7% of the double-tagged spring/summer chinook salmon.

The orifice-based PIT-tag interrogation system in the BWSL missed around 20% of fall chinook salmon, and the antennas in only the upper eight weirs missed almost 40%. Interrogation systems in all of the other fish ladders at Bonneville and McNary Dam detected over 95% of the double-tagged fall chinook salmon except for the system in the Cascades Island Ladder. However, less than 50 fall chinook salmon ascended Cascades Island Ladder, which increased the proportional representation of each undetected fish (each fish represented approximately 2.4%). These results support conclusions from concomitant analyses reported here, which demonstrated that fall chinook salmon used weir overflows in BWSL more than they did in other fish ladders. When we receive the final radiotelemetry data for steelhead, we will conduct a similar analysis.

## VISUAL FISH COUNTS VS. PIT-TAG DETECTIONS

Over the years, people have wondered about the accuracy of visual fish counts at the counting windows. Concerns have been raised because the numbers are derived from a subsample of counts made at the counting window (i.e., numbers are estimated for the break times for the counters and no fish counts occur at night) and there are some human-counting errors. Therefore, now that we have adult PIT-tag detection systems at both Bonneville and McNary Dams, people have asked how well the PIT-tag detections and visual fish counts matched. Here we include an example that compares proportions of spring chinook salmon counted or detected at McNary Dam that were previously counted or detected at Bonneville Dam.

Visual fish counts for adult spring chinook salmon (tagged and non-tagged) during 2002 were 268,813 at Bonneville Dam and 129,357 at McNary Dam (Fig. 5). Thus, 48.1% of the Bonneville Dam total was counted at McNary Dam. The PIT-tag systems at McNary Dam detected 414 (52.5%) of the 789 Snake River adult spring chinook salmon detected at Bonneville Dam (these are fish with ISO tags only). Therefore, the two approaches yielded similar proportions (48.1 and 52.5%) for adult spring chinook salmon.

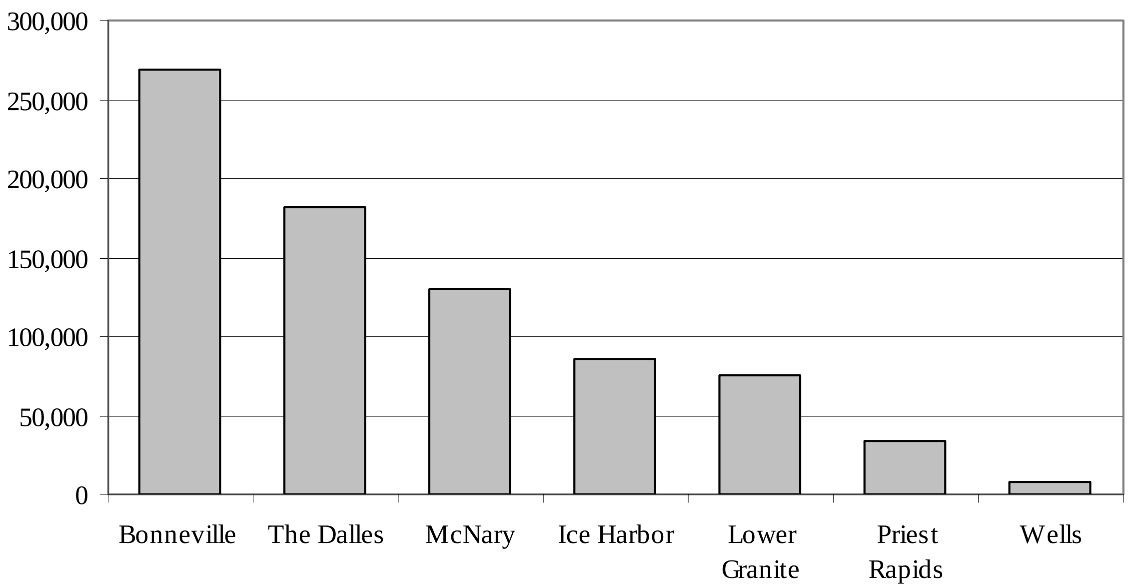


Figure 5. Visual fish counts for adult spring chinook salmon reported for the different dams throughout the Columbia River Basin, 2002.

## PERFORMANCE OF ORIFICE ANTENNAS CONTAINING MOISTURE

### Introduction

During October 2001, NMFS, Destron Technologies, and PSMFC determined that performance in three of the orifice-based antennas in BWSL had significantly degraded, and they suspected the cause was moisture in the antennas. Tests on other antennas suggested there might be moisture in the cable connectors. Both these suspicions were confirmed by tests conducted in December 2001 when the Corps dewatered the ladder. It is important to note that **all** of the antennas were **still reading** tagged fish, but because fish numbers were minimal, it was difficult to distinguish how effectively.

The two most degraded antennas were replaced and dissected to evaluate how the manufacturing process for the fiberglass antennas could be improved. Further investigation revealed that an incompatibility of materials in relation to the manufacturing method caused pinholes to form that could eventually allow water to seep in. In December and January, the manufacturing process for the antenna housings was improved by significantly reducing the amount of foam used in the antenna and by covering the back of the connector plug and surrounding the capacitors with resin. However, around 25% of the fiberglass orifice antenna housings that were installed in 2002 were identified in April as probably containing some moisture (Table 18).

There was insufficient time to modify these antenna housings before the fish ladders had to be watered up. For the antenna housings in the BWSL that had been installed in 2001, the connectors were cleaned and reconnected in 2002 using a new procedure designed to reduce the likelihood of water leakage. No other work was done on the existing antenna housings to make them more watertight.

To investigate the long-term impact of antennas containing moisture, NMFS requested that some antennas in each ladder be set up so that their transceivers reported all reads for each individual fish (i.e., the unique read feature was turned off). Only one read is required to record a fish being present at an antenna, but the variable of the number of reads/fish is a useful tool for demonstrating degradation in performance over time. In addition, all transceivers in BWSL were left set up with the unique read feature off for the entire year to permit comparisons to 2001. When the only evidence required is whether or not a fish was detected at a specific location, we set transceivers to send only a single detection record to the data-collection computer (i.e., the unique read feature is turned on). In September 2002, all transceivers at all ladders were set with the unique read feature turned off so that we could collect baseline information on each antenna.

In addition, each transceiver sends out a status report every 60 to 360 minutes that includes parameter information which can be used to track both short- and long-term problems. For example, the status report can indicate when high temperatures cause internal electromagnetic noise levels to rise significantly (and detune the transceiver). Destron Technologies and PSMFC are still trying to determine which parameter will be the most diagnostic for predicting when an antenna needs to be replaced. They already use certain parameters to determine when an interrogation unit needs maintenance.

Table 18. List of antennas in each ladder that were measured as probably containing moisture between January and April 2002. Information provided by PSMFC.

| Fish ladder | Antenna IDs for antennas containing moisture |
|---|---|
| **Bonneville Dam** | |
| Bradford A branch | 02, 0A, 0F |
| Bradford B branch | 14, 17, 18, 20 |
| Cascades Island | 0F, 10 |
| Washington Shore Ladder (upper section) | 4B, 5B, 7A, 8A, 8B, 9A |
| **McNary Dam** | |
| Oregon Ladder | 07, 08, 0D, 0E, 0F, 10, 11 |
| Washington Ladder | 01, 03, 07, 0E, 0F, 10 |

Three times during the season, PSMFC tested all antennas in the fish ladders with a megohmmeter to determine whether the resistance measurement had changed significantly for any antenna (when resistance between two antenna cables measures less than infinity, the conclusion is that the antenna probably contains moisture). These tests showed that most antennas remained consistent over all sets of measurements, but others did change their status. Furthermore, PSMFC is re-evaluating this test since even a small amount of condensation on the antenna cable can produce a false positive reading for moisture in the antenna. Antennas for which measurements consistently indicated moisture over the entire 2002 season are listed in Table 19. In Tables 20-22, cells containing data from these antennas are shaded.

Table 19. List of antennas in each ladder for which all all sets of measurements made in 2002 indicated that the antenna probably contained moisture. Information provided by PSMFC.

| Fish ladder | Antenna IDs for antennas containing moisture |
|---|---|
| **Bonneville Dam** | |
| Bradford A branch | 02 |
| Bradford B branch | 14 |
| Cascades Island | 0B, 0F, 10 |
| Washington Shore Ladder (upper section) | 5B, 8A, 8B, 9A |
| **McNary Dam** | |
| Oregon Ladder | 08, 0D, 0E, 0F, 10, 11 |
| Washington Ladder | 07, 0E, 0F, 10 |

## Tag-Reading Performance

During 2001 and 2002, NMFS compared the average number of reads/fish in the BWSL (Table 20). April dates were chosen for the analysis in 2002 because the 2001 data were already analyzed, and to have comparable data sets, we needed data that was representative of the results for a similar time period. This comparison showed that the performance of antennas containing moisture in April 2002 was equal to or better than it was in April 2001. Therefore, it appeared that the antennas containing moisture had not degraded over time.

Table 20. Average number of reads/fish for each antenna in the Washington Shore Ladder at Bonneville Dam on two dates in April 2001 and 2002. The table also indicates how many adult salmonids transited a particular orifice or antenna on these dates. Shaded cells indicate antennas that consistently measured as containing moisture.

| Antenna IDs | 2A | 2B | 3A | 3B | 4A | 4B | 5A | 5B | 6A | 6B | 7A | 7B* | 8A | 8B | 9A | 9B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **28 April 2002** | | | | | | | | | | | | | | | | |
| Average | 20.9 | 20.1 | 15.1 | 23.4 | 21.7 | 20.2 | 17.9 | 16.4 | 14.5 | 14.5 | 17.6 | 21.9 | 18.5 | 22.7 | 18.7 | 6.6 |
| Count | 11 | 14 | 12 | 13 | 11 | 13 | 8 | 17 | 10 | 16 | 13 | 15 | 17 | 10 | 17 | 10 |
| **24 April 2001** | | | | | | | | | | | | | | | | |
| Average | 15.5 | 20.4 | 18.2 | 16.0 | 22.7 | 16.8 | 18.3 | 16.9 | 16.2 | 16.6 | 16.3 | 11.6 | 17.2 | 16.5 | 16.9 | 4.7 |
| Count | 24 | 5 | 23 | 6 | 23 | 6 | 21 | 8 | 20 | 9 | 20 | 9 | 21 | 8 | 18 | 10 |

* Antenna 7B was replaced in December 2001

Furthermore, results of a *t*-test showed that the difference between mean numbers of reads/fish for antennas containing moisture (19.1) and those without moisture (18.8) in 2002 was not significant. Excluded from this analysis were antennas 9B, because its reads/fish are affected by a high-voltage line running underneath the orifice, and 4B because its moisture status was unclear. These values are slightly different from those reported in May because of the change in moisture status of a few antennas. However, the results indicate that there was no real difference in tag-reading ability between antennas that contained moisture and those that did not.

Analyses conducted on all ladders from May to September 2002 demonstrated that if the average reads-per-fish was less than five, the antenna was missing fish occasionally. This was clearly demonstrated with data collected after PSMFC set up all transceivers to report repeat detections of individual fish (Table 21). Weir counts were 10-30% less in weirs having one antenna that detected less than 5 reads/fish on average (bold face numbers in Table 21). However, in some ladders, fish tend to use one side of

Table 21. The average reads/fish for each antenna, fish counts, and weir totals collected over several days for the orifice-based interrogation systems in the different ladders at Bonneville and McNary Dams in 2002. Antennas for which most measurements indicated moisture are shaded light; those for which all measurements indicated moisture are shaded dark.

**Bradford A branch (BO1)** August 30-September 4

| Antenna IDs | 10 | 0F[a] | 0E | 0D | 0C | 0B | 0A | 09 | 08 | 7 | 06 | 05 | 04 | 03 | 02[b] | 01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 8.1 | 6.6 | **2.0** | 8.0 | 10.3 | 13.3 | 6.6 | 7.1 | 10.9 | 10.7 | 8.8 | 10.7 | 8.8 | 10.6 | 9.6 | 6.5 |
| SD | 2.2 | 3.1 | 1.4 | 2.7 | 2.7 | 20.0 | 2.7 | 1.6 | 4.8 | 6.9 | 3.0 | 3.3 | 3.4 | 3.6 | 3.4 | 3.0 |
| Fish counts | 23 | 25 | 4 | 27 | 26 | 27 | 22 | 25 | 23 | 29 | 26 | 27 | 25 | 26 | 25 | 22 |
| Weir totals | 48 | | **31** | | 53 | | 47 | | 52 | | 53 | | 51 | | 47 | |

**Bradford B branch (BO1)** August 30-September 4

| Antenna IDs | 20 | 1F | 1E | 1D | 1C | 1B | 1A | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 7.1 | 9.4 | 10.3 | 11.4 | 9.7 | 10.2 | 9.9 | 10.0 | 9.8 | 6.9 | **3.9** | 11.3 | 10.9 | 9.3 | 12.0 | 8.8 |
| SD | 2.8 | 2.8 | 3.6 | 3.7 | 3.1 | 2.8 | 3.3 | 3.8 | 3.3 | 2.3 | 2.2 | 3.3 | 3.0 | 3.2 | 4.1 | 3.8 |
| Fish counts | 39 | 32 | 47 | 29 | 41 | 31 | 44 | 32 | 41 | 31 | 32 | 30 | 39 | 33 | 43 | 35 |
| Weir totals | 71 | | 76 | | 72 | | 76 | | 72 | | **62** | | 72 | | 78 | |

**Cascades Island (BO2)** August 30-September 4

| Antenna IDs | 10 | 0F | 0E | 0D | 0C | 0B | 0A | 09 | 08 | 7 | 06 | 05 | 04 | 03 | 02 | 01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 9.1 | 8.8 | 8.6 | 11.6 | 12.3 | 12.9 | 11.3 | 14.3 | 11.7 | 12.3 | 12.1 | 12.0 | 12.6 | 18.2 | 9.0 | 10.6 |
| SD | 3.9 | 3.7 | 3.1 | 5.5 | 3.9 | 6.2 | 3.7 | 6.3 | 3.8 | 4.1 | 4.6 | 3.5 | 4.3 | 8.3 | 4.3 | 4.4 |
| Fish counts | 26 | 21 | 34 | 18 | 32 | 19 | 33 | 16 | 30 | 20 | 28 | 19 | 30 | 21 | 29 | 17 |
| Weir totals | 47 | | 52 | | 51 | | 49 | | 50 | | 47 | | 51 | | 46 | |

**Washington Shore Ladder (BWL)** July 24-27

| Antenna IDs | 2A | 2B | 3A | 3B | 4A | 4B | 5A | 5B | 6A | 6B | 7A | 7B | 8A | 8B | 9A | 9B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 12.6 | 13.9 | 13.8 | 13.5 | 13.4 | 11.6 | 12.4 | 12.5 | 9.3 | 9.8 | 13.6 | 15.2 | 13.9 | 14.4 | 11.7 | **5.6** |
| SD | 2.8 | 4.3 | 4.2 | 4.1 | 3.9 | 3.7 | 4.4 | 3.1 | 3.9 | 3.5 | 3.7 | 3.8 | 4.6 | 2.9 | 3.4 | 2.9 |
| Fish counts | 44 | 21 | 50 | 19 | 50 | 20 | 53 | 18 | 49 | 19 | 54 | 18 | 57 | 15 | 51 | 14 |
| Weir totals | 65 | | 69 | | 70 | | 71 | | 68 | | 72 | | 72 | | 65 | |

**McNary Oregon Ladder (MC1)** August 30-September 4

| Antenna IDs | 12 | 11 | 10 | 0F | 0E | 0D | 0C | 0B | 0A | 9 | 08 | 07 | 06 | 05 | 04 | 03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | **4.3** | 8.8 | 8.2 | 8.1 | 10.7 | 10.9 | 9.9 | 6.9 | 11.0 | 10.0 | 9.4 | 7.2 | 10.0 | 10.7 | **5.3** | **3.8** |
| SD | 2.2 | 3.2 | 3.0 | 3.2 | 3.7 | 3.7 | 3.2 | 2.5 | 2.9 | 3.4 | 3.6 | 4.8 | 2.4 | 4.2 | 2.4 | 2.4 |
| Fish counts | 50 | 52 | 55 | 54 | 65 | 49 | 62 | 48 | 62 | 49 | 51 | 55 | 51 | 55 | 50 | 43 |
| Weir totals | **102** | | 109 | | 114 | | 110 | | 111 | | 106 | | 106 | | **93** | |

**McNary Washington Ladder (MC2)** August 30-September 4

| Antenna IDs | 10 | 0F | 0E | 0D | 0C | 0B | 0A | 09 | 08 | 07 | 06 | 05 | 04 | 03 | 02 | 01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 11.2 | 8.4 | 12.3 | 10.2 | 11.0 | 2.5 | 4.8 | 13.9 | 12.2 | 8.7 | 14.5 | 8.7 | 10.0 | **2.8** | 9.6 | 12.5 |
| SD | 3.3 | 3.3 | 3.7 | 2.8 | 3.0 | 1.7 | 2.3 | 4.9 | 3.8 | 3.1 | 5.4 | 2.5 | 4.1 | 1.7 | 2.9 | 3.7 |
| Fish counts | 38 | 39 | 40 | 39 | 39 | 19 | 36 | 39 | 43 | 34 | 41 | 35 | 40 | 23 | 41 | 38 |
| Weir totals | 77 | | 79 | | **58** | | 75 | | 77 | | 76 | | **63** | | 79 | |

the ladder more than the other, and in those cases, the impact of antennas with lower average reads/fish was either increased or reduced. That and other fish behavior (i.e., fish do not have to use the orifices, and some fish go up and down within a ladder) make it impossible to conclude at this time whether an average of 5 and up to 9 reads/fish may also mean that some fish are missed. Determination of whether an average of 5 to 9 reads/fish may also mean that some fish are missed is something that needs to be accomplished over the next few years.

Of the nine orifice antennas that averaged less than 5 reads/fish (their average values are bolded in Table 21), only two were from antennas wherein most measurements indicated moisture; none was from the group of antennas wherein all measurements indicated moisture. Thus there must be other reasons besides having some moisture in the antennas for these systems to miss detecting some fish. For example, antenna 9B in the BWSL (which averaged 5.6 reads/fish in the example given, but less when analyzed over other time periods), has a high voltage line transiting under it that definitely impacts its reading ability. In addition, some antennas that averaged less than 5 reads/fish had long antenna cables, others appeared to have poor grounding, and others were in locations that may be impacted by intermittent local electromagnetic interference. Low average reads/fish were also seen in antennas where we frankly do not know the reason for the poor performance. Again, these are new systems and we are still learning how to improve their performance.

Antennas with the unique-read turned off were tracked over the entire season. They generally showed that the average number of reads/fish remained fairly consistent over the season; although as in 2001, it appeared that for some there was a decrease over time (Table 22). Some of this degradation over time may be attributed to the higher summer temperatures affecting the tuning and causing RF noise in the transceivers that masked the tag signal.

Table 22. Number of reads/fish for four antennas in the Washington Shore Ladder at Bonneville Dam for different calendar dates in 2001 (the days we tagged fish) (top) and for some antennas in the McNary Oregon Ladder during 2002 (bottom). Shaded cells indicate antennas that were consistently measured as containing moisture. The consistent but notably lower read numbers from Antenna 03 are shown in boldface.

**Bonneville Washington Shore Ladder**

| | Antenna ID | | | |
|---|---|---|---|---|
| 2001 Calendar dates | 3A | 4B | 7B[a] | 9A |
| 16 Apr | 18.1 | 16.0 | 16.0 | 17.5 |
| 17 Apr | 17.9 | 16.9 | 16.2 | 16.2 |
| 18 Apr | 16.4 | 17.3 | 13.9 | 17.8 |
| 24 Apr | 18.2 | 16.8 | 11.6 | 16.9 |
| 25 Apr | 17.9 | 16.0 | 12.6 | 15.4 |
| 13 Jun | 13.4 | 15.9 | 13.3 | 14.5 |
| 19 Sep | 13.2 | 10.0 | 13.6 | 13.7 |
| 25 Sep | 12.7 | 12.2 | 14.1 | 13.2 |

**McNary Oregon Ladder**

| | Antenna ID | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2002 Calendar dates | 0E | 0D | 0B | 08 | 07 | 06 | 05 | 04 | 03[b] |
| 24-26 May | 13.2 | 12.8 | 7.6 | 11.1 | 10.7 | 12.5 | 13.5 | 7.3 | **3.5** |
| 9-14 Jun | 13.5 | 11.7 | 7.6 | 11.5 | 10.8 | 12.1 | 12.2 | 7.0 | **3.9** |
| 5-8 Jul | 13.7 | 11.4 | 6.6 | 11.0 | 10.5 | 10.8 | 12.1 | 7.2 | **4.2** |
| 19-21 Jul | 11.9 | 9.6 | 6.5 | 10.2 | 8.8 | 10.9 | 9.2 | 6.7 | **3.2** |
| 30 Aug-3 Sep | 10.7 | 10.9 | 6.9 | 9.4 | 7.2 | 10.0 | 10.7 | 5.3 | **3.8** |

## Summary and Conclusions

Around 20% of the antennas installed into the fish ladders at Bonneville and McNary Dams consistently measured as containing moisture over the entire 2002 season. Our comparison of the number of reads/fish at BWSL for April 2001 and 2002 showed that the performance of all antennas in April 2002 was equal to or better than in April 2001. Therefore, it appeared that the antennas containing moisture had not degraded over time. Furthermore, a *t*-test comparing the number of reads/fish between BWSL antennas that contained moisture in 2002 and those that did not showed the difference was not significant, with means of 19.1 and 18.8 reads/fish, respectively. Similar comparisons between antennas with and without moisture in the other ladders also showed no significant differences. Thus, there did not appear to be any difference in the ability of the antennas to read tags based on whether or not they contained moisture.

The average number of reads/fish indicated that antennas with less than 5 reads/fish were occasionally missing detections of PIT-tagged fish. Weir counts were 10 to 30% less in weirs having one antenna that detected on average less than 5 reads/fish. Of the nine orifice antennas that averaged less than 5 reads/fish, only two were from antennas that mostly measured as containing moisture; none was from the definite group of antennas containing moisture. Therefore, other reasons must exist for the poor performance of these systems (e.g., long antenna cables, poor grounding, or electronic noise) besides having some moisture in the antennas. It bears repeating that these are new systems, and we are still learning how to improve their performance.

It is important to note that no antennas failed during 2002. Analyses of all antennas in mid September using number of reads/fish, weir counts, and transceiver antenna current levels did not consistently identify any single antenna that was weak. Thus, PSMFC, NMFS, and Destron Technologies concluded that none of the antennas needed to be replaced during the 2002-2003 dewatering period.

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## REFERENCES

Downing, S. L. 2002. Update on the performance of interrogation systems in fish ladders for adult salmonids.

Downing, S. L., and E. F. Prentice. 2001. Evaluation of the prototype production PIT-tag interrogation system installed into the Washington Shore Fish Ladder at Bonneville Dam. Part 2: Analysis of the data on a per species basis.

(These technical reports are available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097 or posted on the Internet at http://www.pittag.org/web/Adult/index.html )

PSMFC (Pacific States Marine Fisheries Commission). 1996. Columbia Basin PIT Tag Information System (PTAGIS). Pacific States Marine Fisheries Commission, Gladstone, OR. Online interactive database and other related PIT-tag information available at www.psmfc.org/pittag